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A 200-kV neutron generator, II

By I. BARTHOLDSON and G. CARLSON

With 6 figures in the text

In a previous paper one of us[1] described the construction of the neutron generator at the Institute of Physics, Upsala. This paper concerns the adjustment of the generator and some preliminary measurements. The neutron yield of the D(d, n)-reaction was determined as a function of the deuteron energy.

Adjustment of the neutron generator and focusing of the ion beam

The conditions required for obtaining a good focus are summarized as follows:

1. The possibility of retaining the ion beam focused in the target level at all acceleration tensions.
2. The position of the focus in relation to the tube axis must be independent of the high voltage. When the generator is not properly adjusted, the ion beam drifts aside with an increasing voltage of the accelerating lens.
3. Absence of periodical deviations due to loading effects in the tube.

The parameters influencing the path of the beam, which were varied during the adjustments, are:

a. The position of the lower accelerating electrode in relation to the tube axis, adjusted by careful mechanical centering and following fine-adjustment during the watching of the ion beam. The fine-adjustment is brought about by means of the two screws controlling the position of the lower accelerating electrode. They are to be found at B in Fig. 7 of the previous paper.[2]

b. The centering of the ion-optical system, i.e. the ion source, the probe, and the prefocusing lens. The centering is made by careful mechanical adjustment. This is done with a special adjustment tube, which is inserted into the lens system from below.

c. The position of the ion-optical axis of the ion source system in relation to the axis of the accelerating lens. This proved to be of extreme importance. During the adjustment, which has to be made every time the ion source is replaced again, the position and inclination of the ion source is varied, until the lateral position of the focus becomes independent of the accelerating tension. The ion source

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[1] G. CARLSON, Ark. f. Fysik Bd 2, nr 26.

[2] G. CARLSON, loc. cit.

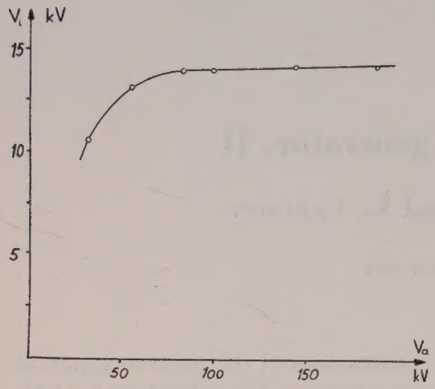

Fig. 1. Voltage V_i of the ion source as a function of acceleration voltage V_a for obtaining a well focused beam.

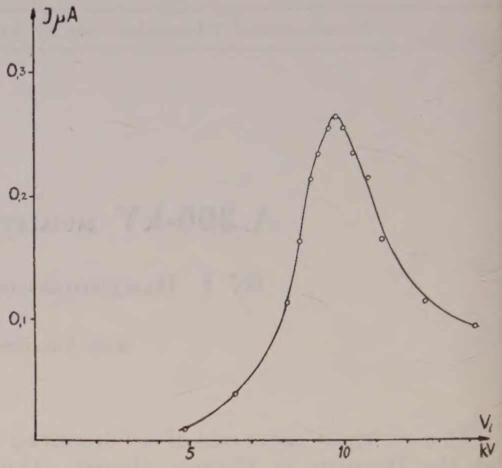

Fig. 2. The ion current on the target as a function of ion source voltage V_i, showing the critical prefocusing tension.

is adjusted by means of screws, which are to be found at E in Fig. 6 of the previous paper.[1]

d. The variation of the focus level with the high tension is compensated by an equivalent alteration of the prefocusing voltage.

When the generator is correctly adjusted, it is possible to obtain a good focusing at all acceleration tensions of up to 200 kV by giving the prefocusing voltage its proper value. This is to be seen from Fig. 1. The figure shows voltage V_i of the ion source as a function of the high voltage when the beam is well focused. The voltage of the prefocusing lens is obtained from V_i by subtracting the constant probe voltage (about 2 kV).

When the high voltage and the probe voltage are given, the adjustment of the prefocusing voltage is critical, as can be seen in Fig. 2. The latter shows the dependence of the ion current as a function of the varied ion source voltage when the acceleration voltage is kept constant. The maximum of the ion current corresponds to the best focus.

The results attained are a focus with a diameter of 1–3 mm and a drift aside less than 1 mm with the high voltage increasing from 10–200 kV. The loading effect mentioned above in item 3, which manifests itself in the periodical deviations of the ion beam from the tube axis, completely disappears when the tube is correctly adjusted as described.

Measurement of ion current

A reliable measurement of the ion current in apparatus of this kind is associated with some difficulties[2, 3]. The problem consists of an effective elimination of the

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[1] G. Carlson, loc. cit.

[2] S. Eklund, Ark. f. Mat. Astr. o. Fysik, 29 A, N:o 7.

[3] J. M. Lyshede, Det Kgl. Danske Vid. Selskab Mat.-Fys. Medd. XVIII, 13.

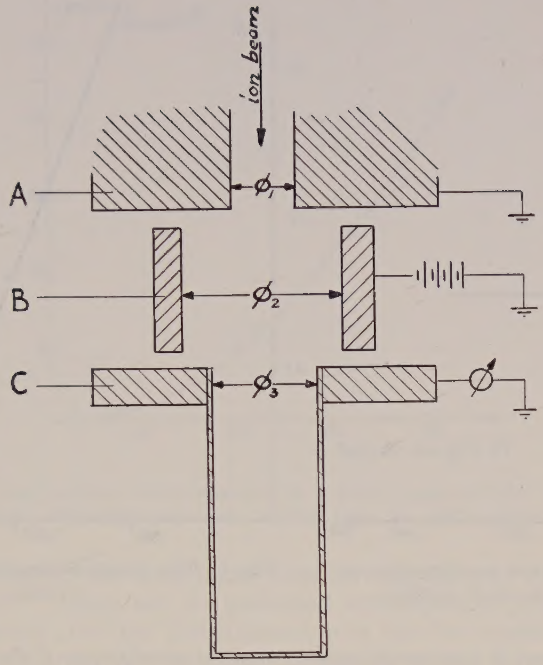

Fig. 3. The Faraday cage with suppressor electrode B.

secondary electrons formed when the beam hits the walls of the tube, the slit, and the target. The ion current was measured with a Faraday cage supplied with a suppressor electrode of a form which was investigated by measurements on a current-flow model, and which proved to give reliable results. Fig. 3 is a sketch of the Faraday cage. It consists of three cylinders insulated from each other with the diameters $\varnothing_1$, $\varnothing_2$, and $\varnothing_3$. The middle one, B, serves as an electrode suppressing electrons released at slit A as well as in Faraday cage C. The relation $\varnothing_1 < \varnothing_3 < \varnothing_2$ must be satisfied so as to obtain a correct measurement of the current. It is important to give the suppressor electrode B a sufficient length — at least half the diameter — because otherwise there will be a low potential barrier between slit A and cage C in comparison with the potential supplied to the electrode. The current-measuring instrument is a vacuum tube μA-meter designed and built by Mr C. Reutersward, fil. lic. The instrument is supplied with four measuring ranges from 0.2–200 μA. In Fig. 4 the ion current is plotted against the voltage of the suppressor electrode. During the measurement of the current it is sufficient to use a constant suppressor supply of –100 V. Under these conditions the secondary electrons are completely eliminated, as can be seen from the figure.

The ion current on the target could be kept constant within 2 % under good conditions. But sometimes we observed very large fluctuations of the current, and always in connection with a pressure variation in the tube. When this phenomenon was further examined, we found the ion current to be strongly dependent on the gas pressure in the tube. The current variation is shown in Fig. 5, which is a plot of the ion current as a function of the gas pressure in the tube. The pressure-depend-

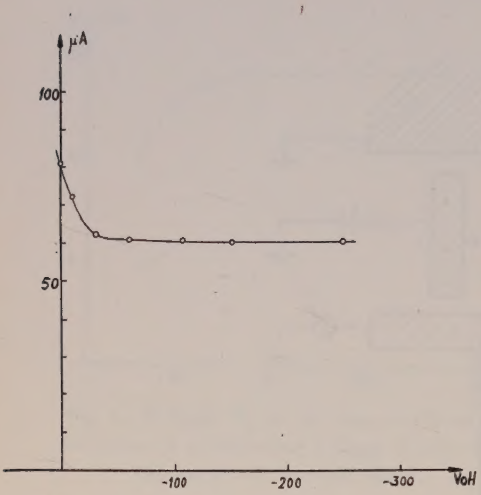

Fig. 4. The ion current as a function of the suppressor electrode voltage.

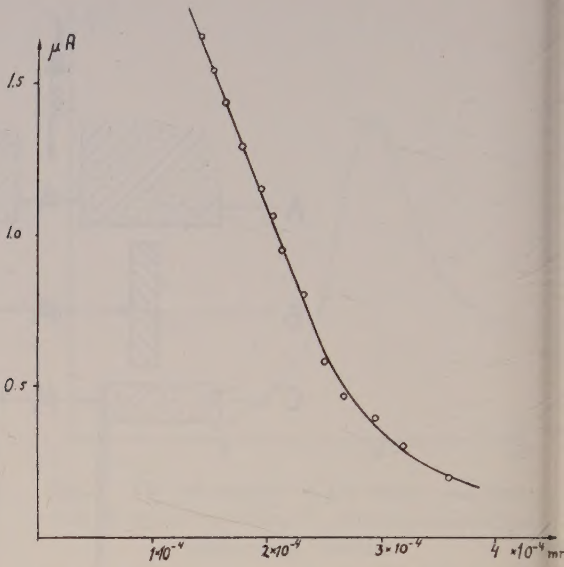

Fig. 5. The pressure-dependence of the ion current.

ence of the current is measured under constant conditions of the ion source. When output currents from ion sources are reported one must have in mind the possibility of losses of ion current due to the pressure, when the ion sources are applied to an acceleration tube.

Neutron yield

The measurements of the neutron yield were carried out by using a heavy-ice target cooled with liquid air. The heavy water used had a purity of 99.6 %. The neutrons were recorded by a screened BF_3-counter surrounded with a paraffin moderator. The counter was connected to a proportional amplifier and a scale of 128. The background of the counter was 3 counts/min., whereas the counting speed during the measurements was of the order of some thousand counts/min. The measurements were made both with atomic (D^+) and molecular (D_2^+) ions. After the measurements were corrected with regard to the background and the neutrons released in the ion separation system, the relative strength was determined in relation to two Ra-Be sources of 100 and 20 mC. A correction as to the difference of energy of the Ra-Be neutrons and the D-D neutrons has not been made. To obtain the total yield, the angular distribution of the D-D neutrons[1] must be considered. So the result as measured at an angle of 90° to the direction of the incident beam was multiplied by

$$\frac{1}{2}\int_0^{\pi} (1 + A\cos^2\Theta)\sin\Theta\, d\Theta = 1 + \frac{A}{3}.$$

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[1] Konopinski and Teller, Phys. Rev. 73, 822 (1948).

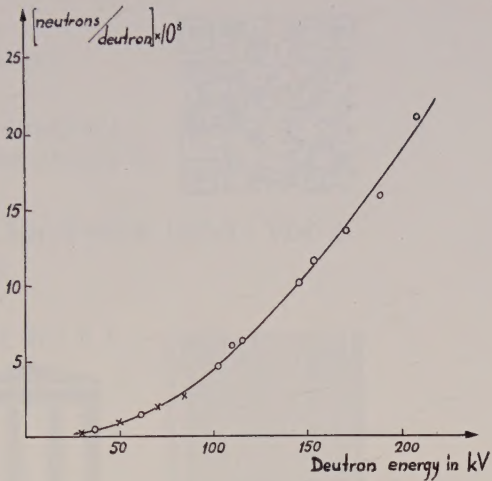

Fig. 6. The neutron yield of the D(d,n)-reaction in a thick target of D_2O as a function of the deuteron energy. Measurements with atomic ions (o), with molecular ions (×).

The value of the A-factor has been taken from investigations of the D(d, p)-reaction recently published.[1, 2] There are no published investigations into the energy-dependence of the factor A of the D(d, n)-reaction in this low energy region, but certain signs indicate that the two reactions are similar in this respect.[3]

If we assume with good reason that the Ra-Be sources give $15 \cdot 10^3$ neutrons per mC and sec., the absolute yield is obtained in neutrons per impinging deuteron. The yield as a function of the deuteron energy is plotted in Fig. 6. The agreement between the yields from atomic and molecular ions is good, as is seen in the figure, and this entitles the assumption of there being a complete purity of the atomic ions separated, which is further underlined by the purity of the heavy water used. The result is in good agreement with the measurements made by Ladenburg and Kanner.[4]

The total yield with the beam not separated is at present equivalent to about 2 Curie of Ra-Be at 200 kV and 80 μA of ion current.

The Physical Institute, University of Uppsala, Dec. 1949.

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[1] Bennet, Mandeville and Richards, Phys. Rev. 69, 418 (1946).

[2] Bretcher, French and Seidl, Phys. Rev. 73, 815 (1948).

[3] Konopinski and Teller, loc. cit.

[4] Ladenburg and Kanner, Phys. Rev. 52, 911 (1937).

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